Arnold Schwarzenegger
Governor

MAINTAIN, ENHANCE AND IMPROVE RELIABILITY OF CALIFORNIA'S ELECTRIC SYSTEM UNDER RESTRUCTURING

APPENDIX - XII

Bidding Strategies for GENCO's in the Short-Term Electricity Market Simulator (STEMS)

PIER FINAL PROJECT REPORT

Prepared For:
California Energy Commission
Public Interest Energy Research Program

Prepared By:

Lawrence Berkeley National Laboratory

CERTS
CONSORTIUM FOR ELECTRIC RELIABILITY TECHNOLOGY SOLUTIONS

MARCH 2006
CEC-500-2006-035-APXII
LBNL-58939

Prepared By:
Lawrence Berkeley National Laboratory
Consortium for Electric Reliability Technology Solutions (CERTS)
Joseph H. Eto
Berkeley, CA
Contract No. 150-99-003

Prepared For:

California Energy Commission

Public Interest Energy Research (PIER) Program

Don Kondoleon,
Contract Manager

Mark Rawson, Bernard Treanton, Linda Kelly, Ron Hoffman, Don Kondoleon
Project Managers

Mark Rawson
Program Area Team Lead

Laurie ten Hope
Office Manager,
ENERGY SYSTESM INTEGRATION AND ENVIRONMENTAL RESEARCH OFFICE

Martha Krebs, Ph. D.
Deputy Director
ENERGY RESEARCH AND DEVELOPMENT DIVISION

B.B. Blevins
Executive Director

Bidding Strategies for GENCO's in the Short-Term Electricity Market Simulator (STEMS)

Atif Debs, Charles Hansen, & Yu-Chi Wu — *Decision Systems International, Atlanta, Georgia, USA*

Peter Hirsch — *EPRI, Palo Alto, California*

Lisa Szot — *California Independent System Operator, Folsom, California*

Abstract

The Short-Term Electricity Market Simulator (STEMS) is developed for variety of users including generating companies (GENCO's) [1], for training, market monitoring, bidding strategy development and studies. GENCO bidding strategies are modeled with a focus on FERC's[1] Standard Market Design (SMD).

The bidding strategy model considers a mix of rational business goals with an eye on learning from experience. An "intelligent agent" approach is employed, although the implementation uses standard programming languages.

The bidding model design considers the product mix traded by the GENCO, the information available (privately and publicly), and the applicable market rules. The concepts are illustrated by examples.

Keywords

Standard Market Design (SMD), Locational Marginal Pricing (LMP), Congestion Management (CM), Intelligent Agents (IA), Unit Commitment (UC).

Introduction

The Short-Term Electricity Market Simulator (STEMS) is a multi-vendor package being developed through EPRI to be used by a variety of users: ISO's[2], RTO's[3], TRANSCO's[4], GENCO's, LSE's[5], ESCO's[6] and regulatory bodies; for the detailed study of day-ahead, same day and real-time market behavior [1]. It can be used for training, market monitoring, bidding strategy development and various other studies. This paper reviews the models used to simulate the bidding strategies of GENCO's with a focus on FERC's Standard Market Design (SMD).

In developing the GENCO bidding strategy model considerations are made to meet the following goals:

(a) Improve (rather than purely maximize) profitability while controlling risk,

(b) Balance long-term strategic goals with short-term ones,

(c) Learn from experience

Although one may think of other possible goals, the ones considered herein correspond to what we believe is a rational form of business behavior. An "intelligent agent" approach is employed, although the implementation uses standard programming languages (like C or Fortran).

A key component of the model design relates to the product mix traded by the GENCO, the information available (privately and publicly), and obviously, the applicable market rules. The concepts of the bidding model are illustrated with simple examples, although the current development is being tested on the entire California market.

The paper covers the following:

- Review of STEMS structure and range of applications
- Forward Market Administration System
- GENCO bidding model
- Conclusions and recommendations

STEMS Structure and Range of Applications

Figure 1 provides the structure and components of STEMS as an open modular system which utilizes existing and new software packages [1,2]. The key to the "openness" of STEMS is the so-called "Common Information Model" (CIM) developed thru EPRI's sponsorship and adopted by as an international standard [3].

---

[1] Federal Energy Regulatory Commission

[2] Independent System Operator

[3] Regional Transmission Organization

[4] Transmission Company

[5] Load Serving Entities (e.g. distribution company, large customer, etc.)

[6] Energy Service Company (e.g. energy broker, power exchange, etc.)

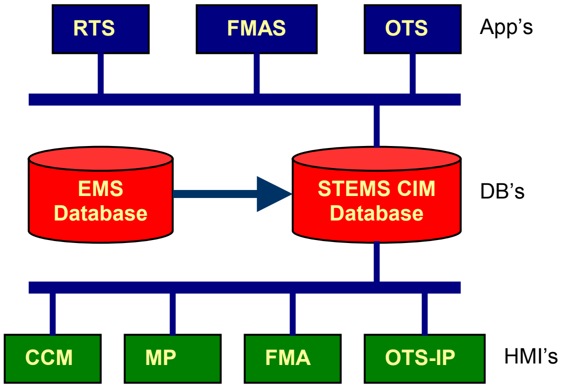

Figure 1: STEMS Modular Structure Based on Open System Standards

Basically, all of the applications communicate with the STEMS CIM database, which in this case, is a commercial real-time database product. The STEMS CIM derived its data from the corresponding Energy Management System (EMS) and additional application specific data. The interfaces between the applications and CIM are designed using special software, called Common Data Source (CDS) modules. This applies to any existing or new applications. The Human Machine Interface (HMI) communicates also with the CIM using screens that can be easily built by the user. The applications modules shown above are:

1. OTS (Operator Training Simulator): The OTS simulates the real-time operation of the power system using a full-scale physical model (network, substations, generating stations, loads, relays, etc.)
2. RTS (Real-Time Market Simulator): The RTS uses Intelligent Agent (IA) technology to simulate the real-time bidding strategy and market clearing/settlement. It has several user options based on specified goals.
3. FMAS (Forward Market Administration System): The FMAS considers the day-ahead and hour-ahead market participant (MP) bids, and clears the markets involved.

The HMI modules are all linked to the STEMS CIM database as follows:

(a) OTS-IP (OTS Instructor Position) – for OTS and STEMS session control, building and monitoring scenarios, and many others,

(b) CCM (Control Center Model) – for simulating the activities of the control center (at the ISO, for example). The CCM can be a replica of the control center hardware and software.

(c) FMA (Forward Market Administration) -- for the running of the market clearing software and communicating the results to the OTS via CIM.

(d) MP (Market Participant) – for monitoring MP bids and associated strategies.

Forward Market Administration System (FMAS)

In Figure 2 we provide the structure of the FMAS. Basically, the FMA module receives bids from the market participants (MP's) and information from both public sources and private ones. The private information is the network and operation data (real-time and other data), and the public ones are demand forecasts, system conditions such as total resources on-line, network conditions, and others).

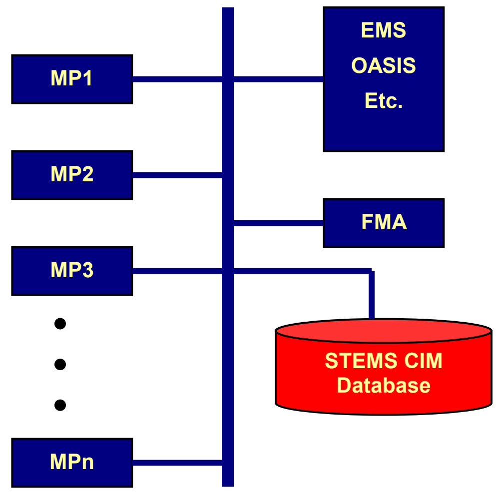

Figure 2: Structure of the Forward Market Administration System (FMAS)

In the FERC Standard Market Design (SMD) generator and LSE bids are "multi-part" bids consisting of (for example in the case of generators):

- Unit available capacity
- Energy supply bid curve for the next period (one day for the Day-Ahead (DA) market)
- No load cost
- Minimum up time
- Minimum down time
- Start-up cost as a function of time needed to start

A typical supply bid curve is shown in Figure 3, whereby there is a critical requirement of being monotonically increasing. The FMA is required to run a "security-constrained unit commitment" program and obtain a secure 24 hours schedule which meets the following:

- Complete load/generation balance based on all generation and demand bids, as well as, the published load forecast by the ISO
- All power flows are within secure limits
- System reserve requirements are satisfied.

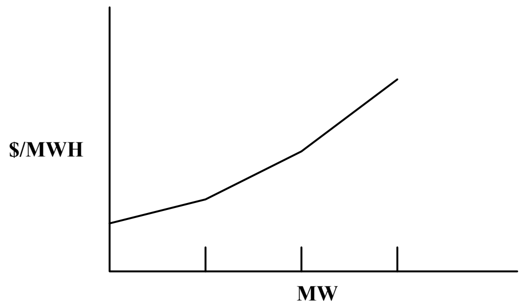

Figure 3: Piecewise Linear Monotonic Bid Curve

In order to satisfy this goal, the STEMS employ two standard control center packages: Unit Commitment and the Optimal Power Flow (see

Figure 4).

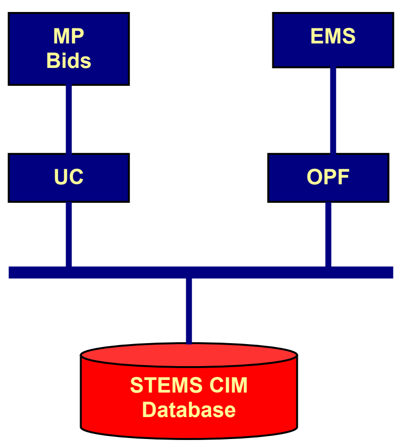

Figure 4: Components of the FMA: UC and OPF

The optimization approach used in obtaining the security-constrained unit commitment schedule consists of the following iterative steps:

1. Bid data and demand forecasts are used to obtain an initial unit commitment schedule. In STEMS the EPRI DYNAMICS package is used whereby the Lagrange relaxation method is used.
2. Given the UC schedule, the OPF is run for every hour in the schedule, and the bus prices are calculated,
3. A congestion check is performed. If no congestion is detected then the process is stopped,
4. If congestion is detected (non-uniform locational prices), then corresponding hourly penalty factors are applied to the unit bid price curves.
5. Steps 1-3 are repeated until convergence occurs.

One can prove that the resulting solution is "optimal" under the assumption the UC solution is truly optimal. Otherwise, the solution is "practically optimal" as judged by the so-called duality gap of the Lagrange relaxation.

GENCO Bidding Strategy

A. Assumptions

The GENCO bidding strategy in STEMS is based on the following considerations:

1. All GENCO's share the same public information as provided by the ISO/RTO, namely: system hourly load forecast, as well as, possible regional (zonal) load forecasts,
2. Past data on clearing prices are also available to all GENCO's,
3. A GENCO does not have access to competing generator data (fuel costs, heat rates, planned outages, etc.). However, a GENCO can "estimate" such data by studying publicly available data on the competition,
4. Network information is not available to the GENCO's[7]
5. In the short-term (day ahead), the only uncertainties considered by each GENCO are:
    a. Demand forecast uncertainty
    b. Uncertainties in market price forecast
    c. Uncertainties in the estimates of competitors' cost and technical information.

B. General GENCO Bidding Model

The general GENCO bidding model consists of four interacting components:

1. Model of "own" resources – unit heat rates, fuel costs, forced outage rates, unit capacities, historical hourly outputs, historical bid curves, hourly payments, profits and losses,
2. Model of the market – this may consist of models of all competing generators using estimated data, or a general model using price forecasts as will be shown below,
3. Model of future uncertainties – demand and price forecasts, as well as uncertainties in competing generators data
4. Bid curve optimization model – based on the above models and assumptions given in subsection A above.

The following discussion goes through a sequence of approaches to obtain the GENCO bid curves.

[7] This assumption may be relaxed in future phases of STEMS development.

of modeling the competition thru the MCP curve (Figure 5).

C. Method 1: Bid Curve Using Full UC Model

In this method, the following steps/assumptions are used.

(a) GENCO A (the one being optimized) uses own actual heat rates and fuel costs,

(b) GENCO A assumes estimates of other GENCO heat rates and fuels costs. Based on that the user postulates possible bid curves for these other GENCO's.

(c) GENCO A runs a series of UC runs, using a different bid curve in each case. For each run, the company profit is computed.

(d) The optimal bid curve is selected as the best in the group.

(e) The process is repeated for all the GENCO's and the final bid curves are then forwarded to the FMA.

For a large system, this method may be very time consuming. One way out is to simplify the unit commitment model by ignoring the discrete variables.

D. Method 2: Bid Curve Using Simplified Market Model

In this method, the following steps are used.

(a) GENCO A (the one being optimized) uses own actual heat rates and fuel costs,

(b) The rest of the GENCO's are represented by a single must-run generator, with the following characteristics:

   i. Its capacity is the sum of all remaining generator capacities,

   ii. Its cost curve corresponds to the historical market clearing price curve as a function of total output. This is derived from a regression model (See Figure 5).

(c) Run the UC for GENCO A for each bid curve and compute resulting profit as in Method 1.

(d) Select the most profitable bid curve and repeat same process for all GENCO's.

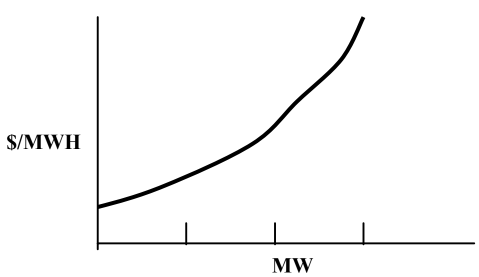

Figure 5: Estimated Historical Market Clearing Price (MCP) Curve

In this method the UC model is usually small and hence is not time consuming. It is still limited by the selection of a proper population of scenarios. It has the clear advantage of modeling the competition thru the MCP curve (Figure 5).

E. Incorporation of Uncertainties

Methods (1) and (2) yield bid curves for each generator under deterministic assumptions. In order to incorporate the uncertainties mentioned above, the following approach is suggested:

(a) For each Day-Ahead market run, obtain a set of scenarios consisting of (1) demand forecast, (2) Competitor bid curves (for Method 1) or MCP curve for Method 2.

(b) Calculate the probability of each scenario,

(c) Obtain the bid curves and corresponding profits for each generator,

(d) Select the weighted average bid curve as the one to send to the FMA.

F. Incorporation of Historical Performance

The profit estimate used in the bid optimization procedure cannot be adjusted until the true MCP is generated by the FMA. The bid curves are then adjusted for the next round using a profit error estimate from the historical data. The adjustment rules will be described is a later paper.

Conclusions and Recommendations

The main conclusion of this paper is that realistic bidding strategies for generators in the FERC SMD can be developed using mostly standard software products. The STEMS architecture which is based on the Common Information Model (CIM) allows for an open system implementation.

The proposed bidding strategies are sufficient for use in a simulation environment whereby the use can adjust the parameters associated with competitors' data, uncertainties, and own company goals. Although the software used is not that of Intelligent Agents, the concepts are based on IA thinking but with flexibility of implementation to allow for the use of highly sophisticated software, such as the EPRI Unit Commitment program.

The development reported herein is in the development phase with test results expected by the end of April, 2003.

Acknowledgements

The developments reported in this paper have been partially sponsored by EPRI, Palo Alto, California, California Energy Commission (CEC), Lawrence Berkley National Laboratory, LBNL (under the Consortium for Electric Reliability Technology Solutions, CERTS) and the National Science Foundation (NSF).

References

[1] A. Debs, Yu-Chi Wu and C. Hansen, "Development of an Electricity Market Simulator," [Contribution to book entitled, "The Next Generation of Electric Power Unit Commitment Models," B. F. Hobbs, et al

(Editors), Kluwer Academic Publishers, Norwell, MA (2001)]

[2] X. Guan, "Integrated Resource Scheduling and Bidding in the Deregulated Electric Power Market: New Challenges," [Contribution to book entitled, "The Next Generation of Electric Power Unit Commitment Models," B. F. Hobbs, et al (Editors), Kluwer Academic Publishers, Norwell, MA (2001)]

[3] X. Guan, Yu-Chi Ho and F. Lai, "An Ordinal Optimization Based Bidding Strategy for Electric Power Suppliers in the Daily Energy Market," IEEE Transactions on Power Systems, Vol. 16, No. 4, Nov. 2001.

[4] A. Debs, Yu-Chi Wu and C. Hansen, "Design of an Effective Electricity Market Simulator," IEEE Computer Applications in Power, January issue, 2000.

[5] "*Enabling Technologies and Systems for the Business-Driven Electric Power Industry*," Proceedings of Conference sponsored by EPRI, Palo Alto, California, organized by, Decision Systems International, Atlanta, Georgia, and held in Vienna, Austria, November 2-4, 1999.

[6] A. Debs and C. Hansen, "The EPRI-OTS as the Standard for Training and Studies in the New Era: Strategy for Global Application," Presentation at the First Asia Pacific Conference on Operation and Planning Issues in the Emerging Electric Utility Environment, sponsored by EPRI, Kuala Lumpur, Malaysia, August 11-14, 1997.

[7] A. Debs, Modern Power Systems Control and Operation, Kluwer Academic Publishers, Norwell MA, 1988.

[8] B. Sheblé, Computational Auction Mechanisms for Restructured Power Industry Operations, Kluwer Academic Publishers, Boston, Massachusetts, 1999.

[9] A. Papalexopoulos, "Design of the Wholesale Market in the USA," Proceedings of the EPRI Second European Conference – Enabling Technologies & Systems for the Business-Driven Electric Utility Industry, Vienna, Austria, November, 1999.

[10] Y. C. Wu, A. S. Debs and R. E. Marsten, "A Direct Nonlinear Predictor-Corrector Primal-Dual Interior Point Algorithm for Optimal Power Flows," IEEE Transactions on Power Systems, Vol. 9, No. 2, May 1994, pp. 776-883.

[11] A. Debs, "The OPF in the Deregulated Environment," Lecture notes for intensive short course by Decision Systems International entitled: Modern Power Systems Control and Operation, held in San Francisco, CA, March 1996.

[12] Y. C. Li and A. K. David, "Optimal Multi-Area Wheeling," IEEE Transactions on Power Systems, Vol. 9, No. 1, Feb. 1994, pp. 288-294.